

FLAVOR OF FRESH-CUT GALA APPLES IN BARRIER FILM PACKAGING AS AFFECTED BY STORAGE TIME

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ABSTRACT

Our objective was to determine flavor quality changes, and measure changes in key volatile compounds, sugars and acidity, in fresh-cut Gala apples packaged in film to control the atmosphere during distribution. Gala apples were washed, cored, sliced, dipped in a browning inhibitor and packaged in a barrier film. After 0, 5, 9, 12 and 14 days at 1C, the apple slices were evaluated for descriptive flavor attributes, gas chromatographic volatiles, sugars, pH and titratable acidity. Flavor attributes, sweet aromatic flavor and sweet taste had a maximum intensity between 5 and 9 days. Sugars remained constant. Results suggest that perceived flavor intensity increased the first few days after preparation and packaging, then dissipated. Compounds that decreased during storage were farnescene, hexyl hexanoate, 2-methyl-butyl hexanoate; hexyl 2-methyl butanoate and hexyl butanoate decreased until 10 days, then started to increase. Hexyl acetate and hexane increased during storage.

INTRODUCTION

Little sensory research has been published on the flavor quality of fresh-cut apples, or other fresh-cut produce. The fresh-cut produce industry, which includes freshly prepared fruits and vegetables, is estimated to be \$10 billion, which was 10% of total produce industry sales. Retail fresh-cut fruit has sales

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of \$1 billion annually (Anon. 1999). Fresh-cut Granny Smith and Fuji apples are currently available and are a small portion of the fresh-cut fruit total sales. Fresh-cut produce sales have steadily increased over the last several years. Most of the growth has been in fresh-cut vegetables. Due to shorter shelf-lives and fresh-cut fruit being more susceptible to storage quality challenges, the fresh-cut fruit industry has been slower to grow. Apples, melons and pineapple were some of the first to be used commercially for fresh-cut fruit. There has been much published about microbial quality but very little about eating quality. Good flavor is a critical factor in maintaining the customers who purchase fresh-cut produce (Anon. 1999).

Whole apple flavor has been examined extensively by measuring aromatic compounds using gas chromatographic analysis (Dimick and Hoskin 1983; Yahia 1994). Much of this work was done on Red Delicious, Golden Delicious, Granny Smiths, McIntosh, Rome and Cox's Orange Pippin apples held in air or in controlled atmosphere (CA) storage. Williams and Knee (1977) found that stage of maturity at harvest affected the increase of volatiles upon ripening after CA storage. After prolonged CA storage, the aroma does not develop in the same manner as tree-ripened fruit. Plotto *et al.* (1999) found that Gala apples stored in CA had a decrease in volatile production as well as a decrease in fruity flavor. Air storage after CA storage increased volatile production, but the sensory panel did not perceive an increase in fruity flavor. Fellman and Mattheis (1995) found that ester content decreased in Rome apples during six days at ambient storage. Ester volatiles were low after six months' storage regardless of storage condition, and their formation appeared to be a phenomenon related to ripening. Ueda *et al.* (1993) measured higher amounts of butyl acetate and 2-methylbutyl acetate at the beginning of storage at 8C in Starking Delicious apples. As senescence proceeded, ethyl alcohol and ethyl esters became more predominant. Young *et al.* (1996) identified the volatile compounds isolated from Gala apples. All of the compounds they found had been previously reported by Dimick and Hoskins (1983) in other apple cultivars. They compared sensory attribute changes to various concentrations of added volatile compounds. Increasing levels of 2-methylbutyl acetate and butanol resulted in an increase in 'overall flavor and aroma'. Sweet aroma increased with increased concentrations of hexyl acetate and 2-methylbutyl acetate. 'Apple aroma and flavor' increased with increasing levels of 2-methylbutyl acetate, butanol and hexyl acetate. 'Red apple aroma and flavor' were associated with 2-methylbutyl acetate, hexyl acetate and butanol; typical 'apple aroma' consisted of 'green apple' and 'woody apple' where 'red apple aroma' described typical apple flavor. Daillant-Spinnler *et al.* (1996) evaluated sensory attributes of 12 cultivars of apples in relation to consumer acceptance. They evaluated appearance, odor, flavor and texture; and compared these attributes to consumer preference in the United Kingdom. Texture and taste were more important to these consumers than aroma and

appearance. Royal Gala apples were characterized as sweet. Stebbins *et al.* (1991) compared hedonic rating of several apple cultivars. Royal Gala apples were rated 5.2 on a 9-point scale. Cultivar, harvest time and storage condition are all important to fresh-cut apple quality, but the literature is lacking in the effect of fresh-cut storage on apple flavor.

The objective of this research was to monitor flavor changes, volatile compounds, pH, titratable acidity and sugars in fresh-cut Gala apples in barrier film packaging during the storage.

MATERIALS AND METHODS

History of Apples

Gala apples were purchased from Rice Fruit Company, in Gardners, Pennsylvania. They were harvested on September 14, 1996, and stored in controlled atmosphere (CA) of 1.4% O₂ and 2.5-3.0% CO₂ at 0C until December 6, 1996. When they were removed from CA, they were stored for two months in refrigerated air. Then they were shipped to the USDA Southern Regional Research Center, New Orleans, Louisiana via overnight delivery where the fresh-cut product was prepared. At this time they were considered fully mature to slightly over-mature based on ethylene production rates of 8.21 ± 0.6 $\mu\text{L/kg/h}$ described by Watada and Massey (1981) and firmness tests (described below).

Fresh-cut Preparation

Prior to cutting, apple firmness was tested with the McCormick Fruit Tester penetrometer with a 11 mm probe, Model FT3-27, Yakima, Washington. Readings ranged from 53.4 to 62.3 N. Unblemished apples were washed and sanitized for 1 to 2 min by holding in 100 ppm chlorine solution prepared from sodium hypochlorite and adjusted to pH 6.5 to 7.0 with citric acid monohydrate. Apples were then rinsed and towel dried. A thin slice (approx. 1/4 in.) was removed from the top and bottom of the apple, and discarded, before cutting the apple into 10 wedges with a 2.06 cm core removed from the center of the apple using a stainless steel apple corer/wedger. An additional 2-3 mm was removed from the core side of each wedge to minimize browning. Any small blemishes or bruises were cut away. Apple wedges were submerged in a holding solution of 0.25% NaCl, to prevent browning and keep apples firm until sufficient number of wedges were ready for browning inhibitor treatment. Apples were submerged in a solution of 4% sodium erythorbate and 0.1% calcium chloride anhydrous (Sapers and Miller 1998) for 1 min at a ratio of 6 to 8 apples per 2 L of solution. Gentle agitation was used to assure all surfaces were submerged. All solutions were at 24C. Apple wedges were dewatered by placing

them into a salad spinner and spun at approximately 15 to 20 rpm for 10 revolutions. Randomly selected wedges (85g) from 11 apples were placed in a heat sealable (15.5 cm × 22 cm) bag formed from a barrier film (P640B, Cryovac, Div. of W.R. Grace and Co., Duncan, SC). There were 18-20 wedges per bag. The oxygen permeability was 15 cc/m²/day. The bag openings were towel dried and heat sealed. Packaged apples were stored at 1C for up to 14-days, and were evaluated at 0, 5, 9, 12, 14-days. Apple preparation was designed to allow all storage times to be presented to the panel on one day for a given replication (2 replications on the same lot of apples took place 2 weeks apart). The 0-day samples were cut, treated with browning inhibitor and analyzed without sealing in bags. The purpose of the experiment was to observe flavor changes during storage and since all samples were presented on the same day no nonbrowning inhibitor treated samples were evaluated, because panelists would be able to pick out stored samples on sight alone. A bias on browned samples would have resulted.

Flavor Evaluation

Descriptive flavor analysis (Meilgaard *et al.* 1991) was used to assess changes in apple flavor during the 14-day storage period. The terms used for describing apple flavor are in Table 1. Five wedges (from at least four different bags) equilibrated to 24C were placed in glass custard cups and covered with inverted watch glasses that extended at least 13 mm over the edge of the cups. The cups were labeled with 3-digit random numbers. Panelists slid the watch glass back to allow the headspace to enter the nose. They evaluated the intensities of the various aromas emitted from the samples. Then they placed one wedge in their mouth and chewed to prepare for swallowing, but expectorated the sample. All flavor descriptors were evaluated for intensity. If the intensity of a particular aroma was more intense during chewing than it was during smelling, then the higher score was recorded, and vice versa. If chewing a second chunk resulted in different intensity perceptions, then a mental average score was recorded for final analysis. The intensity scale was based on the Spectrum method (Meilgaard *et al.* 1991). It is a 0-15 scale with 0 being no flavor detected while 15 is more intense than could normally be experienced in apples. A warm-up sample (a locally purchased Washington fancy grade Red Delicious apple) was presented first. Thereafter, the experimental samples were presented monadically in random order within a session. All panelists received the samples in the same order. All five sampling times (0, 5, 9, 12, and 14 days) were presented at one session. Two sessions consisted of one replication per session. Eleven trained panelists were used in this experiment. Panelists rinsed with filtered water between samples and used unsalted saltine crackers to cleanse their palates.

TABLE 1.
APPLE FLAVOR DESCRIPTORS AND DEFINITIONS

Term	Definition
Fruity	The aromatic associated with general fruit aroma/taste such as pears, melons, and pineapples.
Raw/Ripe apple	The aroma/taste associated with fresh apple top-notes or newly harvested ripe apples.
Floral	Aromatics associated with dried flowers, such as lilacs and/or wild flowers. The aromatic is characterized as spicy floral as in an "old fashioned sachet."
Sweet aromatic	A sweet impression such as caramel or honey which may appear in the aroma, and/or aromatics, and/or taste.
Brown spice	The aromatic associated with cloves, cinnamon, vanilla, or nutmeg.
Green/grassy	The aromatic associated with unripe fruit, green grass, or weeds.
Vinegar/vinegar cider	Aromatic associated with vinegar.
Citrus	Aromatics associated with fresh citrus products. (examples: lemon candy or fresh cut oranges)
Waxy	Aromatic commonly associated with candle wax.
Woody	The aromatic associated with fresh cut lumber.
Musty	Aromatic associated with mold or dirt such as geosmin and MIB.
Fermented	The aromatics associated with fermented fruit or sugars such as apple wine.
Chemical	Aromatics commonly associated with solvents, cleaning compounds, and hydrocarbons. (Reference: Fresh mashed strawberries vs. strawberry jam)
<u>TASTES</u>	
Sweet	The taste on the tongue associated with sugars.
Sour/tart	The taste on the tongue associated with citric acid or sweet tarts.
Bitter	The taste on the tongue associated with caffeine.
<u>MOUTHFEEL</u>	
Astringent	The chemical feeling factor on the tongue described as puckering/dry, and associated with strong tea.

Gas Chromatographic Analysis

Samples were analyzed by gas chromatography (GC) the same day the sensory panel evaluated them. Bags were opened, subdivided into ca. 40-g samples, and each sample placed in a 125-mL Erlenmeyer flask. The flasks were sealed with a Teflon™ tape and placed into a 40C water bath. When the work was done septums did not exist for these flasks. After 30 min a temperature equilibrated solid phase microextraction (SPME) fiber with a 100 μ m thick polydimethylsiloxane film (Sepelco, Inc., Bellefonte, Penn.) was exposed to the headspace above each sample for 20 min. This was a variation of the work of Matich *et al.* (1996). The SPME fibers were then retracted and sealed until analysis by GC/flame ionization detection (FID). SPME fibers were desorbed in the GC injector at 250C for 1 min. The temperature program on the column was held at 50C for 1 min then ramped to 250C at 10C/min. The GC was equipped with a 60 m by 0.32 mm i.d. column with a 1.8 micron thick 5% phenyl methyl silicate film (J&W Scientific, Folsom, CA.). Additional samples of treated and untreated apples were run by SPME with all conditions being the same and analyzed by GC equipped with a mass selective detector (Hewlett Packard, Palo Alto, CA.). Compounds were preliminarily identified by library search (Wiley Library). Identities of most compounds were confirmed by analysis of authentic compounds (Sigma-Aldrich Chemical Co., Inc., Milwaukee, WI; Fluka Chemical Corp., Ronkonkoma, NY).

Analysis of Sugars and Acids

All slices (approx. 85 g) in the sample bag were homogenized at 25C for 30 s using a Waring blender. The homogenate was diluted 50% with deionized water and 40 g added to 70 mL of 80% ethanol, boiled for 15 min, cooled and vacuum-filtered through Whatman #4 filter paper. The extract was brought up to 100 mL with 80% ethanol and then 20 mL was passed through a C-18 Sep Pak (Waters/Millipore, Milford, Mass.) and 0.45 μ m Millipore filter. The filtered extract was injected into a 20- μ L sample loop, into a Perkin Elmer Series 410 HPLC system. Sugars were analyzed using a Waters Sugar Pak column at 90C with a mobil phase of 100 μ M ethylenediamine-tetraacetic acid disodium-calcium salt (CaEDTA) and a flow rate of 0.5 mL/min. A Perkin Elmer LC-25 Refractive Index detector was used to measure sugar concentrations. Filtered analytical grade reagents were used for standard preparation to establish HPLC retention times and calibration. This method was adapted from Baldwin *et al.* (1991). Titratable acidity by titration with NaOH was measured on the 50% diluted apple homogenate according to Jones and Scott (1984).

Data Analysis

Panelists' scores were graphed and compared visually. If a trend obviously existed for an attribute based on the majority of the panelists and one or two panelists deviated greatly from this trend, then they were deemed outliers and their scores were discarded for that attribute only (Bett *et al.* 1993). To statistically analyze the data, the panelists' scores (minus outliers) for a sample at a given session were averaged and used for further analysis. The intensity values of the two means were plotted over the storage time and mathematical equations were derived from the curves. Because of the continuous nature of storage data, the intensity values were regressed onto storage time using Proc Reg in SAS (SAS Institute Inc., Cary, NC). Significant change over time was indicated by the significance of the fitted regression models. A flat line that does not change over time indicates no significance (Neter *et al.* 1985). Gas chromatographic data were analyzed in a similar manner. The three GC runs for a replication were averaged and the two replications were used in the curve-fitting analysis. Factor analysis of standardized GC and sensory data (standardized to mean = 0 and standard deviation = 1) was done on means of compound peak areas and flavor intensities that exhibited a change over time (statistically significant or not). Three factors were used based on eigen values greater than 1. The principal factor method on correlation matrix was used to generate results using Proc Factor (SAS Institute, Inc., Cary, NC).

RESULTS AND DISCUSSION

The fresh-cut apples typically underwent flavor changes during the 14-day storage period. Some (6 out of 14) descriptive flavor attributes increased to a maximum between 5 and 9 days and then intensity leveled off or declined. Sweet aromatic flavor and sweet taste had statistically significant (probability of 0.1 or less) quadratic changes (Fig. 1). The maximum intensity of sweet aromatic occurred between days 5 to 9 and decreased between days 12 to 14. The maximum intensity for sweet taste occurred at 5 days and decreased thereafter. However, instrumental analysis of sugars (fructose, sucrose and glucose) displayed no significant trends during the storage time (data not shown). Therefore, the presence of sugar alone does not explain the change in sweet taste. Lack of correlation may be due to changes in various organic acid concentrations that possibly mask sweetness. Sour taste had a significant quadratic trend, and was lowest around 5 days and was highest after 12 days ($Y = 1.17 + 0.06 X - 0.002 X^2$, $R^2 = 0.62$, $p = 0.03$, $RMSE = 0.16$). The range in intensity was 1.2 at 5 days to 1.6 at 12 days. Meanwhile, pH decreased between day 0 and day 9, then leveled off (data not shown). Percent titratable

acidity increased for 9 days, then decreased (data not shown). However, neither pH nor titratable acidity correlated with sour taste.

Fruity flavor, which does not include apple flavor, manifested a smooth linear increase for 9 days, but a small change (2.8 at 12 days and 3.4 at 9 days thereafter). Between 9 and 12 days, the flavors became more variable. Therefore at days 12 and 14 the fruity flavor was unpredictable (standard deviations >0.5). Astringent mouth feel increased slightly over the storage period (1.2 at 0 day to 1.4 at 14 days). The day-0 astringent scores were more variable than

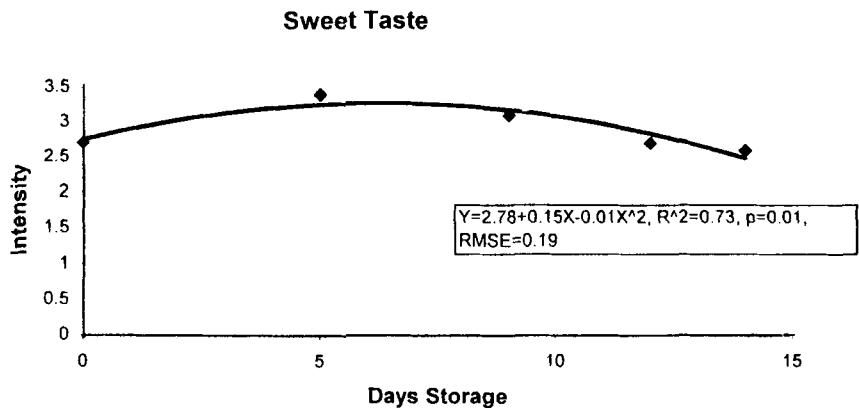


Fig. 1a

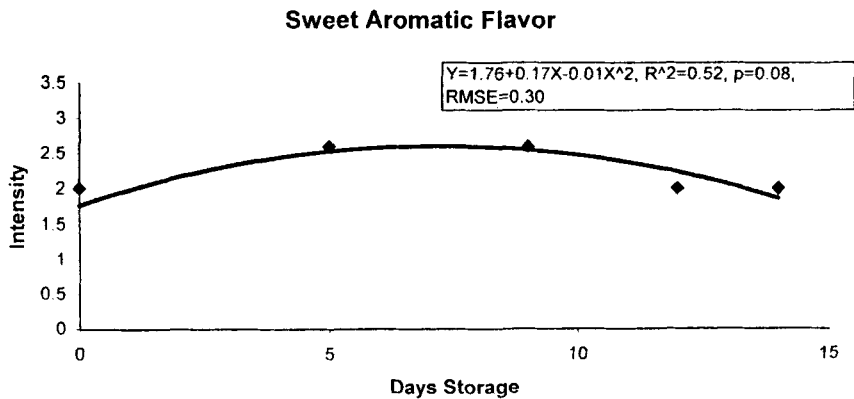


Fig. 1b

FIG. 1. CHANGES IN SELECTED FLAVOR DESCRIPTOR DATA OF FRESH-CUT GALA APPLES DURING 14-DAYS STORAGE AT 1C WITH SIGNIFICANT CHANGE BASED ON REGRESSION ANALYSIS

those determined after 5 days or longer; analyzing the data excluding the day 0 resulted in a linear trend ($Y = 1.18 + 0.01X$, $R^2 = 0.51$, $p = 0.05$, $RMSE = 0.05$). The intensity scores for "fermented" for session 2 were consistently more intense than those for session 1 for all storage times, but no significant trends were found (data not shown). All of the apples were treated the same for both sessions except that session 2 whole apples were stored whole at 1C for two weeks longer. Raw apple flavor had no significant trend although raw apple flavor tended to peak at days 5 and 14 (intensity = 3.0, it was 2.6 at day 0). Unpublished data (Bett 1996) indicate that the raw apple flavor of Red Delicious apples is consistently more intense at day 7 than at days 0 and 14. Overall, the flavor quality of the 14-day stored fresh-cut Gala apples remained good. Off-flavors such as fermented and vinegary did not increase significantly during storage under these conditions. Raw apple flavor did not decrease significantly over the 14 day storage period, although fruity increased during the first 9 days then decreased (no statistically significant trend though). The flavor intensities changed after 9 days, but the 14-day samples had some fresh apple characteristics in spite of the flavor changes, and no overwhelming off-flavors developed under these storage conditions.

Gas Chromatographic Analysis

Of the compounds monitored, only hexane, ethyl 2-methyl-butanoate, hexyl acetate, hexyl butanoate, hexyl 2-methyl-butanoate, propyl hexanoate, hexyl hexanoate and farnescene changed significantly during storage. See Fig. 2 to see trends for the aroma active compounds only.

Another compound, which has been tentatively identified as hexane, had a significant quadratic trend that decreased between days 0 and 5, then increased until day 12 where it leveled off ($Y = 1960 - 96.6 + 25.8X^2$, $R^2 = 0.68$, $p = 0.02$, $RMSE = 1161.7$). Hexane has a high odor threshold and is not aroma active (Cunningham *et al.* 1986). Ethyl 2-methyl butanoate has a significant quadratic trend that decreased in intensity from 0 to 5 days, then increased through 14 days (Fig. 2). Flath *et al.* (1967) found that when smelling the GC effluent, ethyl-2-methyl-butanoate had a threshold concentration of 0.1 ppb and they thought it to be a primary component responsible for the odor of Golden Delicious apples. Hexyl acetate had a significant linear trend increasing from day 0 until day 12 where it leveled off at days 12 and 14 (data not shown, $Y = 9700X + 143000$, $R^2 = 0.46$, $p = 0.03$, $RMSE = 58415$). Young *et al.* (1996) determined this compound to be important in Gala apple flavor. Hexyl butanoate had a significant quadratic trend that was lowest at 11 days, but the largest decrease was between 0 and 5 days (Fig. 2). It occurs after CA storage (Lavilla *et al.* 1999). Hexyl 2-methyl-butanoate had a significant quadratic trend decreasing from 0 until 9 days and then increased slightly (Fig. 2). Another

2-Methyl-Butyl Hexanoate

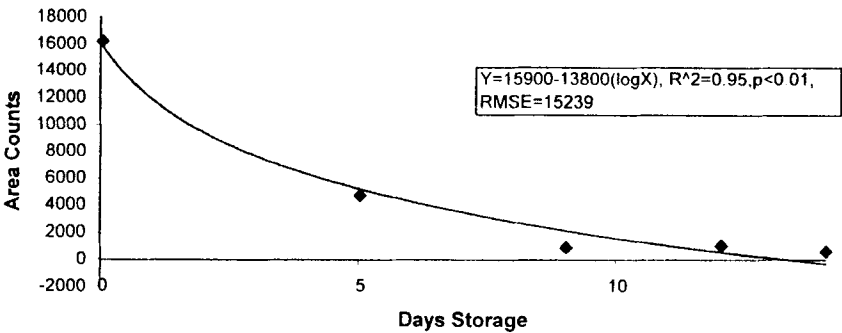


Fig. 2a

Hexyl Hexanoate

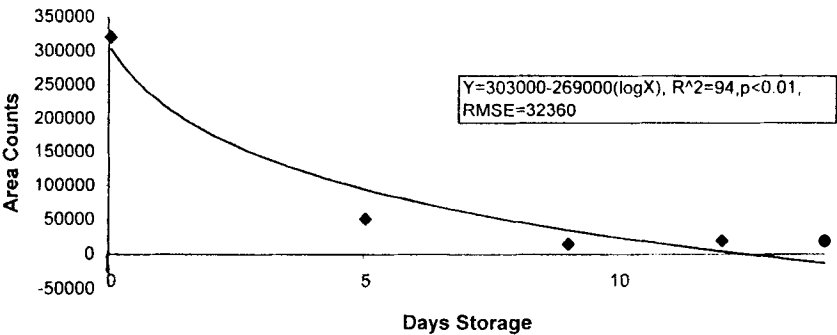


Fig. 2b

Ethyl 2-methyl butanoate

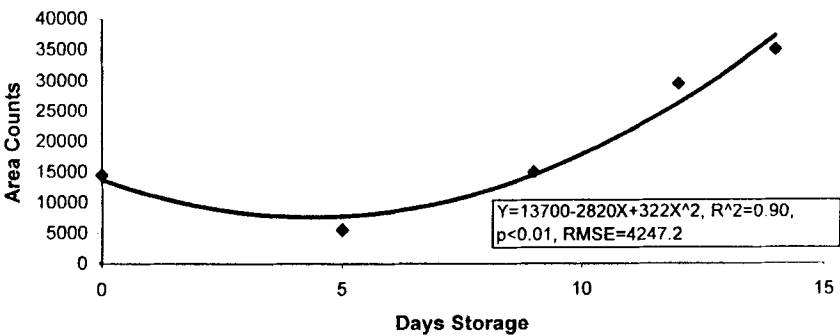


Fig. 2c

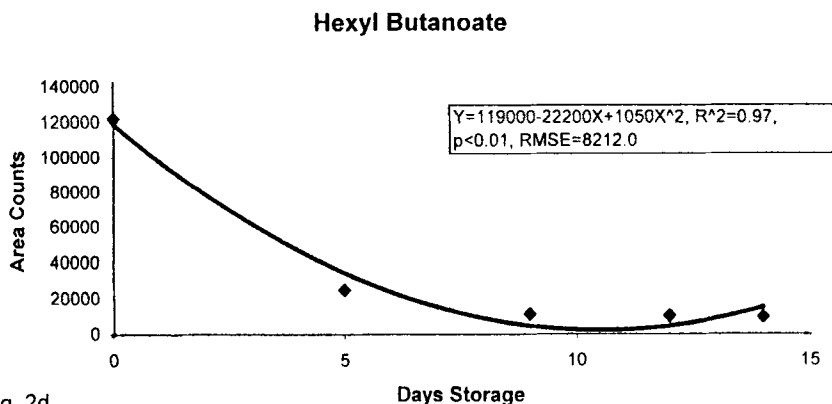


Fig. 2d

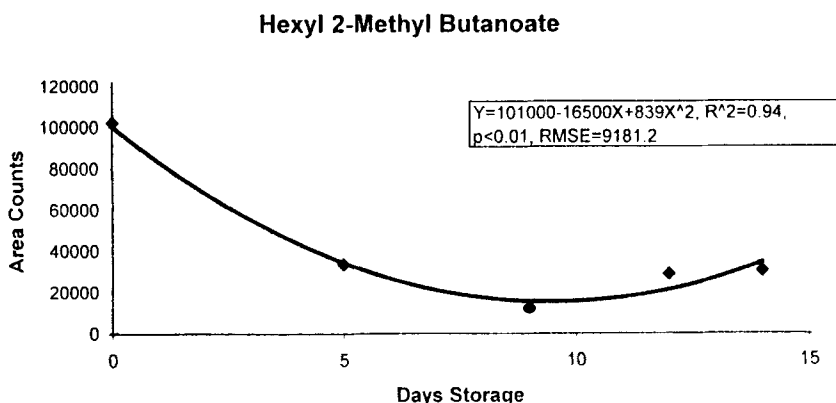


Fig. 2e

FIG. 2. CHANGES IN SELECTED AROMATIC COMPOUNDS IN FRESH-CUT GALA APPLES DURING 14-DAYS STORAGE AT 1°C WITH SIGNIFICANT CHANGE BASED ON REGRESSION ANALYSIS

peak has been tentatively identified as 2-Methyl-butyl hexanoate (Fig. 2). It had a significant logarithmic (\log_{10}) trend that decreased from day 0 to day 9 then leveled off. Hexyl hexanoate had a significant logarithmic trend that decreased from day 0 to day 9 and then leveled off through day 14 (Fig. 2). Farnescene had a significant logarithmic trend that decreased between 0-day and 9-days, then somewhat leveled off (data not shown, $Y = 2040000 - 1270000 (\log X)$, $R^2 = 0.83$, $p < 0.01$, $RMSE = 274000$). Farnescene has a high odor threshold and is not known to have much effect on apple flavor.

Factor Analysis

Recognizing that Factor Analysis was done on a select data set and that the total number of treatment combinations was at a premium, there were some interesting patterns. The flavor attributes sweet aromatic, sweet taste, fruity and chemical flavors loaded positively on Factor 1 (Table 2). Hexyl butanoate, with a sweet, fruity, pineapple aroma, loaded positively with these flavor attributes. Hexyl acetate, farnescene and hexyl hexanoate loaded negatively with the flavor attributes in Factor 1. Hexyl acetate and hexyl hexanoate have apple, cherry, pear, floral, and fresh vegetable, fruity aromas, respectively. Hexyl butanoate with its fruity and sweet notes seems to fit well in this factor, but hexyl acetate and hexyl hexanoate, with their fruity-like aromas do not load positively with fruity in this Factor.

TABLE 2.
FACTOR ANALYSIS LOADINGS^a OF SELECTED COMPOUNDS AND FLAVOR
DESCRIPTORS OF FRESH-CUT GALA APPLES STORED FOR 14 DAYS AT 1°C

	Factor 1	Factor 2	Factor 3
Hexyl butanoate	0.98	-0.14	-0.13
Sweet aromatic	0.93	0.36	0.05
Fruity	0.89	0.07	0.15
Sweet	0.83	0.17	0.35
Chemical	0.80	0.53	-0.12
Hexyl acetate	-0.86	0.51	-0.09
Farnescene	-0.97	0.20	-0.14
Hexyl hexanoate	-0.98	-0.21	0.02
Sour	-0.13	0.88	-0.44
Astringent	-0.49	0.87	0.01
Woody	-0.48	0.77	0.34
Ethyl 2-methyl butanoate	0.58	0.77	0.24
2-Methyl-butyl hexanoate	0.24	-0.97	0.07
Hexyl 2-methyl butanoate	-0.22	-0.97	0.05
Raw apple	-0.19	0.53	0.72
Hexane	0.45	0.40	-0.73
Eigen values	7.76	5.86	1.65

^a Based on Principal Factor Method. Factors were limited to three based on Eigen values more than 1.

Flavor attributes, sour taste, astringent and woody loaded positively on Factor 2. Ethyl 2-methyl butanoate loaded positively on Factor 2, while 2-methyl-butyl hexanoate and hexyl 2-methyl hexanoate loaded negatively on Factor 2. Ethyl 2-methyl butanoate has a green, fruity, pungent aroma and hexyl 2-methyl butanoate has a sweet, fruity, green aroma. The relationships between

these flavors and compounds are not known. Therefore it is uncertain why one loaded positively and the other negatively.

Raw apple flavor loaded positively on Factor 3 and hexane loaded negatively. Hexane has a green, grassy aroma which may be more apparent when raw apple flavor intensity is less intense.

Based on GC-olfactometry analysis and descriptive sensory analysis, Young *et al.* (1996) reported that 2-methylbutyl acetate and hexyl acetate were important contributors to the flavor of New Zealand grown Royal Gala apples. In this experiment 2-methyl butyl acetate did not change during fresh-cut storage. Ingram *et al.* (1998) reported that ethyl esters were produced from acetate esters in Red Delicious, fresh-cut apples packaged in low permeability film for seven days. They found that higher molecular weight acetate esters, with the exception of 2-methyl butyl acetate, decreased with time in fresh-cut storage. We found that the acetates in the fresh-cut Gala apples did not change much with time or they increased as in the case of hexyl acetate.

Sweet aromatic flavor had a similar trend to hexyl acetate, and they loaded on the same factor in Factor Analysis. "Fruity" flavor and hexyl acetate appeared to have similar trends for the first nine days. Hexyl acetate has been described as having a fruity/floral aroma (Dimick and Hoskin 1982). It is likely that the "fruity" flavor sensory term involves many more compounds than just hexyl acetate which may be a contributor.

Hexyl butanoate, hexyl hexanoate, farnescene and 2-methyl butyl hexanoate decreased drastically between 0 and 9 days and leveled off. Since none of the flavor attributes displayed this trend, it is uncertain what role these compounds play in apple flavor. Hexyl butanoate loaded positively with fruity and sweet flavor. Hexyl hexanoate, and farnescene loaded negatively. The compound 2-methyl butyl hexanoate loaded on the second factor.

As apples mature they produce acetate esters. After maturation these compounds start to decrease (Mattheis *et al.* 1991b; Hansen and Poll 1992). Hexyl acetate production increases in controlled atmosphere stored apples. But, at 20C in room atmosphere, they decrease (Lavilla *et al.* 1991; Mattheis *et al.* 1991a). Upon cutting for fresh-cut apples, hexyl acetate increased during storage, suggesting a reaction to wounding. Ethyl 2-methyl butanoate increased during CA storage and during storage at 20C (Lavilla *et al.* 1999; Jun and Bangerth 1996). In fresh-cut 'Gala' apples it decreased between 0 and 5 days then started to increase. Hexyl butanoate was detected in apples after CA storage. After that it did not change during storage at 20C (Lavilla *et al.* 1999). During fresh-cut storage hexyl butanoate decreased until 11 days, then it started to increase slightly. This may be a temperature dependent compound.

CONCLUSIONS

Fresh-cut Gala apples had fairly stable flavor quality during storage in that no significant off-flavors developed. Sweet aromatic and sweet taste increased until 9 days, then decreased slightly. Other flavors did not change much. The changes in sugars did not relate to sensory descriptor intensity changes. Most of the monitored flavor compounds decreased during storage. Texture quality was not evaluated, but could be critical in the acceptance of fresh-cut apples.

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